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HUMAN FACTORS PLAN FOR MARITIME SAFETY: ANNOTATED BIBLIOGRAPHY

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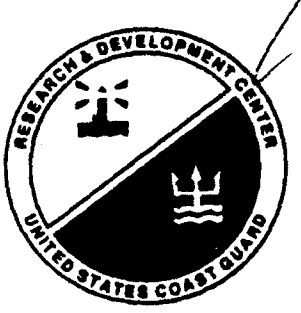

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15. Supplementary Notes

This report documents the literature review which was completed for the Human Factors Planning project. It is a supporting document to the main report, "Human Factors Plan for Maritime Safety," which will be published later. The Coast Guard technical contact and COTR is Dr. Anita Rothblum, (203)441-2847.

16. Abstract

This report summarizes a collection of papers related to the application of human factors to the maritime industry. These papers describe: human factors problems in the maritime industry, research designed to offer solutions, and research in other domains that may apply to these and other potential problems encountered in the maritime industry. This report has been divided into six sections, each dealing with a particular area of interest: automation, fatigue/incapacitation, manning, navigation, organizational factors, and training. Each summary includes the complete citation, a synopsis of the methodology used, issues addressed, principal findings, and any technical problems or deficiencies.

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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	* 2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
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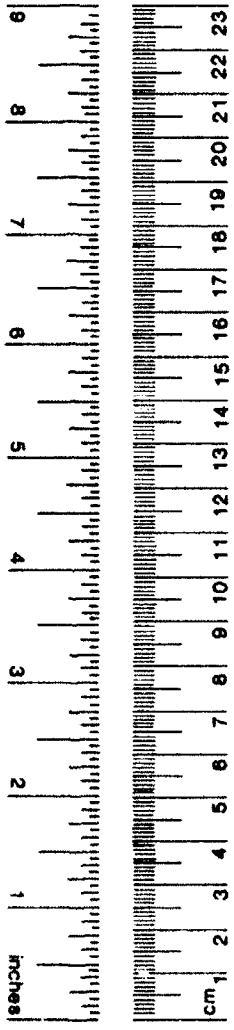
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly).



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

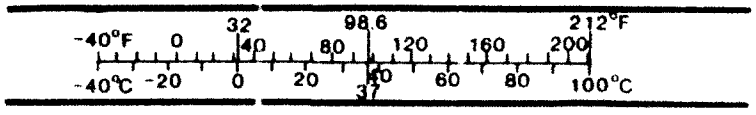


TABLE OF CONTENTS

INTRODUCTION

This volume is a collection of papers related to the application of human factors to the maritime industry. Some papers, written by human factors professionals, specifically address maritime human factors issues, while others document accidents or describe the need to apply human factors during ship design and operation. Some papers included in this bibliography do not apply directly to the maritime domain; however, their content relates to many of the issues facing the maritime industry. Together, these papers describe human factors problems in the maritime industry, research designed to offer solutions, and research in other domains that may apply to these and other potential problems encountered in the maritime industry.

The following paragraphs present a brief discussion concerning the content and organization of the information contained in each summary. Six sections follow (automation, fatigue/ incapacitation, manning, navigation, organization, training), with each addressing separate human factors problems. Each section contains a short introduction, a reference list, followed by an alphabetical compilation (by author) of summaries for all the papers in the topic area. This volume ends with a complete reference list. Each reference in this list is identified by topic area, so that this list serves as an index to locate specific summaries. Likewise, the reference list, that precedes the summaries in each topic area, acts as a table of contents, identifying papers included in each section.

Each summary contains eight fields that classify the paper and describe its content, findings, and limitations. The Citation field is self explanatory, containing the complete reference for the paper. The fields Area of Focus and Mode/Industry classify the papers by the issues they seek to resolve and the domain for which they were developed. Area of Focus refers to the issue areas that these papers address, and provides the basis for organizing the papers. In many instances, papers address more than one area. In these cases the summary included the multiple areas, and the paper was classified according to the most predominant issue. The areas of focus and their definitions follow:

- Automation: Indicates a focus on how humans interact with highly sophisticated technology.

- Fatigue/Incapacitation: Indicates a focus on ship safety and the factors of fatigue and incapacitation due to motion sickness and substance abuse.

- Manning: Indicates a focus on the personnel requirements needed for safe operation.

- Navigation: Indicates a focus on human limits and technological devices associated with navigation.

- Organizational: Indicates attention to the relationship between human performance and the organization of the ship/shipping industry.

- Training: Indicates attention to identifying and developing requisite knowledge, skills, and abilities.

The Mode/Industry field refers to the transportation mode or industry that the paper addresses most directly. Many of these papers attempt to resolve issues in the maritime industry. However, much human factors research has focused on other domains, and many of the findings in these domains may apply to the maritime industry. The domains included in this review consist of:

- Maritime
- Military
- Process Control
- Aviation
- Basic Research
- Nuclear Energy
- Mining

The next two fields, Type of Paper and Methodology describe the nature of the paper and process used in its creation. The type of paper ranged from empirical examination of human performance limitations to descriptions of recent developments in maritime technology. The complete list of paper types and definitions follows:

- Empirical: Based on data collected through laboratory research, simulator research, or field studies.

- Accident analysis: Based on an examination of accident and near accident situations.

- Commentary: Based on author's opinion and expert knowledge.
- Theoretical: Consists of an attempt to integrate and explain a broad range of results and findings.
- Review: Based on a collection of previous theoretical or empirical data.
- Model development: Consists of developing a formal model of human behavior.
- Product description: Describes the features of sophisticated hardware or software for ships.
- Regulation/Standard: Based on formal rules, regulations, guidelines, statutes, and standards.

The methodology used to create the paper was not applicable in many cases. In other cases it referred to the specific experimental data collection techniques, such as laboratory studies compared to field studies. Because of the many potential methodologies the following is a representative list:

- Observation
- Task network simulation
- Laboratory study
- Simulator study
- Field study
- Survey
- Prototype development
- Annotated bibliography
- Task analysis

The final three fields describe the content of the paper. More specifically, they describe the main purpose of the paper (Issue addressed), the primary findings or issues resolved (Principal finding), and any technical problems or limitations (Deficiencies).

AUTOMATION

Technological innovations have already led to major changes in the role of the human onboard ships. During the 1960s ship design shifted from manned to unmanned engine rooms. Since then technology has continued to advance and the future promises further changes that may lead to radical changes in the humans' role in maintaining the safe and efficient operation of ships. Harding (1975) lists a wide variety of functions that may be affected by automation, including automatic data logging, position fixing aids, restricted channel navigation aids, collision avoidance systems, cargo planning, automatic route following, and diagnostic aids. Many modern ships already include these functions, and many more functions will be included into future ships. Therefore, as technological capability increases the need to develop an understanding of how technological innovations influence the ability of the ships' personnel to maintain the safe and efficient operation of the ship also increases. This section present a compilation of references concerning automation in the maritime and other domains.

Reference List

46 Code of Federal Regulations, Part 50 et al. (1988, May 18). Part II: Department of Transportation/Coast Guard, Vital system Automation; Final Rule. Washington, DC: U.S. Government Printing Office.

Automated Information Management, Inc. (1989). Human factors engineering long range plan and cost estimation for fiscal years 1990-1994. (Report No. DTCG23-87-A-20031, T.O. 88-0001). U.S Department of Transportation, U.S. Coast Guard.

De Keyser, V.D. (1987). How can computer-based visual displays aid operators? International Journal Man-Machine Studies, 27, 471-478.

Froese, J. (1987). Current development in Federal Republic of Germany regarding crew reduction and bridge automation. Presented at 1987 Ship Operations, Management and Economics International Symposium. Kings Port, NY. Jersey City, NJ: The Society of Naval Architects and Marine Engineers.

Gill, E.W.S. (1989, Spring). Operating an integrated navigation system at sea. Journal of the Honourable Company of Master Mariners, 17(197), 646-655.

Habberley, J.S. (1989, February). Research to investigate on-man bridge operations at night. Seaways, p. 8.

Hansen, A. (1989). One-man control from the bridge. Shipbuilding Technology Int., pp. 275-277.

Harbour, J.L. & Hill, S.G. (1990). Using HSYS in the analysis of human-system interactions: Examples from the offshore petroleum industry. Proceedings of the Human Factors Society 34th Annual Meeting, (pp. 1190-1194).

Harding, E.J. (1975, March). Computer-based ship automation developments in the United Kingdom and abroad. Proceedings of the Symposium on the Use of Computers in Shipboard Automation (pp. 11-26). London: The Royal Institution of Naval Architects.

Holder, L.A., Morrision, J., & Taylor, A.R. (1975, March). Potential applications for computer-based automation: Operational requirements and benefits. Proceedings of the Symposium on the Use of Computers in Shipboard Automation (pp. 27-41). London: The Royal Institution of Naval Architects.

Kristiansen, S., Rensvik, E., & Mathisen, L. (1989). Integrated total control of the bridge. Advance copy of paper to be presented at the Annual Meeting of the Society of Naval Architects and Marine Engineers.

Paetow, K. (1987). Ship of the future. Presented at 1987 Ship Operations, Management and Economics International Symposium, Kings Port, NY. Jersey City, NJ: The Society of Naval Architects and Marine Engineers.

Wilkinson, H.C. (1975, March). Ship automation and the future - An introductory paper. Proceedings of the Symposium on the Use of Computers in Shipboard Automation. (pp. 1-10). London: The Royal Institution of Naval Architects.

Citation

46 CFR Part 50 et al. May 18, 1988. Part II: Department of Transportation/Coast Guard. "Vital System Automation; Final Rule."

Area(s) of Focus

Automation, manning

Mode/Industry

Maritime (Offshore oil platform)

Type of Paper

Regulation/Standard

Methodology

Issue Addressed

Automation implementation, manning, maintenance, and alarms.

Principal Finding

Deficiencies

Section on CRTs makes bold claims about the equivalencies of a single CRT display and what can be perceived from an annunciator panel in a single glance - these are unsubstantiated, and can not be considered as regulatory license to design without proper HF guidelines.

Citation

Automated Information Management, Inc. (1989). Human factors engineering long range plan and cost estimation for fiscal years 1990-1994. (Report No. DTCG23-87-A-20031, T.O. 88-0001). USDOT, United States Coast Guard.

Area(s) of Focus

Automation, manning, fatigue/incapacitation

Mode/Industry

Maritime

Type of Paper

Commentary

Methodology

Issue Addressed

Implementation of human factors principals into Coast Guard regulations.

Principal Finding

Discussion of activities, resources and costs associated with implementing human factors into the Coast Guard

Deficiencies

This report fails to specify human factors concerns that might be of particular importance to the marine industry. In addition, it lacks detail describing specific human factors issues.

Citation

De Keyser, V. D. (1987). How can computer-based visual displays aid operators? International Journal Man - Machine Studies, 27, 471-478.

Area(s) of Focus	Mode/Industry
Automation	Process Control (Steel Casting, Power Generation) Hospital and Power distribution center

Type of Paper

Empirical

Methodology

Field study, comparative study of four systems.

Issue Addressed

Computer-based displays to support decision-making.

Principal Finding

By examining how operators control computer systems this study identified four principles that operators use to structure and simplify problems: 1) Structuring, 2) Differentiation, 3) Economy, 4) Checking.

Computer-based displays can help integrate data, understand time dynamics, logical reasoning; however, they represent only one of many channels of information used by the operators.

Through a functional analysis of operators' information channels (computer-based displays, telephones, and direct contact) this study illustrates some tentative design considerations that might better support operators.

Deficiencies

The domains examined may not correspond to the special problems of the maritime industry.

Citation

Froese, J. (1987). Current development in Federal Republic of Germany regarding crew reduction and bridge automation. Presented at 1987 Ship Operations, Management and Economics International Symposium. Kings Port, NY. The Society of Naval Architects and Marine Engineers: Jersey City, NJ.

Area(s) of Focus

Automation, manning

Mode/Industry

Maritime

Type of Paper

Commentary

Methodology

Issue Addressed

Manning reductions through changes in crew structure and increased automation.

Principal Finding

Introduces a new crew concept, the nucleus crew, that, together with increased automation, will enable ships to operate with a crew of 12.

Deficiencies

Provides little evidence concerning how this manning structure could accommodate emergencies. Also, it provides little specification of exactly what type of automation would be required.

Citation

Gill, E.W.S. (1989, Spring). Operating an integrated navigation system at sea. Journal of the Honourable Company of Master Mariners, 17(197), pp. 646-655

Area(s) of Focus

Automation

Mode/Industry

Maritime

Type of Paper

Commentary

Methodology

Subjective experience

Issue Addressed

Navigation with an integrated navigation system (INS)

Principal Finding

The paper provides a function description of INS. It indicates that workload for 2nd Mate is reduced, if chart position files have been created. It concludes that INS can provide useful information during dense traffic and fog. Problems includes: long response time, possible overload of operator input, lack of help, poor documentation, and lack of initial training. This paper suggests a "familiarization voyage."

Deficiencies

Description of use pattern would seem to lead to possible riskier ship handling in traffic/fog situations.

Citation

Habberley, J.S. (1989, February). Research to investigate one-man bridge operations at night. Seaways, p. 8.

Area(s) of Focus

Automation, manning

Mode/Industry

Maritime

Type of Paper

Empirical, review

Methodology

Literature search, field study

Issue Addressed

One-man bridge

Principal Finding

Reports Norwegian field study that has shown one-man bridge to be effective.

Deficiencies

Field study approach to manning issues may be insufficient because normal operating conditions may not demand two crew on the bridge, but abnormal situations may require more than one.

Citation

Hansen, A. (1989). One-man control from the bridge. Shipbuilding Technology Int., pp. 275-277.

Area(s) of Focus

Automation, manning

Mode/Industry

Maritime

Type of Paper

Product description

Methodology

Issue Addressed

Centralized location of cargo, navigation and engine room information to reduce manning, improve safety, and improve efficiency.

Principal Finding

The authors claim that economic pressure will make a centralized control room a requirement, including a wide variety of information on the bridge, and providing sophisticated optimization features will enhance ship performance.

Deficiencies

The authors include no mention or guidance of how to integrate human into system. They assume that simply because information is on the screen it will be assimilated by the operators.

Citation

Harbour, J.L., & Hill, S.G. (1990). Using HSYS in the analysis of human-system interactions: Examples from the offshore petroleum industry. Proceedings of the Human Factors Society 34th Annual Meeting, pp. 1190-1194.

Area(s) of Focus

Automation

Mode/Industry

Maritime (offshore drilling)

Type of Paper

Accident analysis

Methodology

Issue Addressed

Factors contributing to accidents in offshore oil platforms

Principal Finding

HSYS provided a useful framework for analyzing the accident reports.

Most accidents were a result of poor situational awareness; operators failed to detect the dangerous situations.

Deficiencies

Citation

Harding, E.J. (1975, March). Computer-based ship automation developments in the United Kingdom and abroad. Proceedings of the Symposium on the Use of Computers in Shipboard Automation (pp. 11-26). The Royal Institution of Naval Architects, London.

Area(s) of Focus

Automation

Mode/Industry

Maritime

Type of Paper

Review

Methodology

Issue Addressed

Impact of automation

Principal Finding

Provides more detailed taxonomy of automation, related to ship areas (bridge, deck & engineering) (p. 17). Reviews developments in a number of countries.

Deficiencies

Citation

Holder, L.A., Morrison, J., & Taylor, A.R. (1975, March). Potential applications for computer-based automation: Operational requirements and benefits. Proceedings of the Symposium on the Use of Computers in Shipboard Automation (pp. 27-41). The Royal Institution of Naval Architects, London.

Area(s) of Focus

Automation, manning

Mode/Industry

Maritime

Type of Paper

Commentary

Methodology

Cost/benefit analysis of automation

Issue Addressed

Impact of automation

Principal Finding

This paper presents a functional description of navigation, engine and cargo automation systems; describes benefits that would accrue and cost reductions. In addition, it proposes totally automated liquid cargo control. This paper also examines manning implications and concludes bridge is most likely focus of reduction, since engineers will be kept on to perform day maintenance.

Deficiencies

Lack of detail on cost benefit analysis.

Citation

Hughes, D. (1989, August). Glass cockpit study reveals human factors problems. Aviation Week & Space Technology, pp. 33-36.

Area(s) of Focus

Automation

Mode/Industry

Aviation

Type of Paper

Methodology

Field study, observation, survey

Issue Addressed

Effect of automation on safety and workload.

Principal Finding

The study found that programming the Flight Management System (FMS) requires undivided attention which may lead to failing to a failure to safely manage the plane. In addition, pilots may lose flight skills with highly automated systems, and grow to rely too heavily upon automation.

One of the most striking findings of this study is that automation often responds in ways even experienced pilots find surprising.

Deficiencies

No clear relation between problems with aircraft automation and shipboard automation. Some of the problems associated with aircraft may not be relevant to marine industry.

Citation

Kristiansen, S., Rensvik, E, & Mathisen, L. (1989). Integrated total control of the bridge. Advance copy of paper to be presented at the Annual Meeting of the Society of Naval Architects and Marine Engineers.

Area(s) of Focus

Automation, navigation

Mode/Industry

Maritime

Type of Paper

Empirical

Methodology

Simulator experiments used objective workload (based on simulator scenario) measures to contrast with subjective workload. The field study relied upon a questionnaire and observations.

Issue Addressed

Viability of integrated bridge control and its effect on workload

Principal Finding

The study found no change in workload during low workload periods. In addition, the integrated bridge showed a 35% lower workload rating, compared to the standard bridge during high workload periods. Although the integrated bridge resulted in a large decrease in workload during difficult transits, the overall impressions of the personnel resulted in a bimodal distribution with respect to the perceived workload reduction, illustrating the controversial nature of the new technology.

Deficiencies

Although this paper presents a thorough description of the features of the new bridge design, some of the experimental procedures may jeopardize the validity of the results. For example, subjects only received 30 minutes of training with new design before testing. In addition, the study only compared objective and subjective assessments of workload, but no other performance measures. Other details of the experiment were unclear. For example, the study failed to state whether the conventional bridge was manned by one or two men.

Citation

Paetow, K. (1987). Ship of the future. Presented at 1987 Ship Operations, Management and Economics International Symposium. Kings Port, NY. The Society of Naval Architects and Marine Engineers: Jersey City, NJ.

Area(s) of Focus

Automation

Mode/Industry

Maritime

Type of Paper

Commentary

Methodology

Issue Addressed

Development of the German "ship of the future".

Principal Finding

This paper describes the efforts made to develop a highly economical ship. These efforts include changes in hull design and increased automation. The increased automation promises to facilitate crew reductions without increased workload. One of the developments aimed at crew reduction is the "ship operating center" where all bridge and engine room information is concentrated.

Deficiencies

While this paper provides an excellent overview of the German "ship of the future" it only provides a brief mention of human factors and ergonomics. More detail concerning their efforts to reduce workload, while concentrating responsibilities on fewer people, is needed.

Citation

Wilkinson, H.C. (1975, March). Ship automation and the future - An introductory paper. Proceedings of the Symposium on the Use of Computers in Shipboard Automation (pp. 1-10). The Royal Institution of Naval Architects, London.

Area(s) of Focus

Automation

Mode/Industry

Maritime

Type of Paper

Review

Methodology

Issue Addressed

Impact of automation

Principal Finding

This paper proposed a useful taxonomy for automation:

Machinery: closed-loop control; bridge control of main propulsion; surveillance systems; machinery safety systems; electric generating plant

Bridge automation: navigation; look-out; ship control

Communications & Cargo operations: Auto-distress alarms; automatic reception and transmission of business data.

This taxonomy may be useful for manning analyses.

Deficiencies

No discussion of interfaces or training.

FATIGUE/INCAPACITATION

Reports of fatigue among workers in the maritime industries are common. The long work hours (i.e., greater than 8 hours per shift), the split work schedules required by the three-watch system, and environmental factors such as foul weather combine to create conditions highly conducive to acute and chronic fatigue. Perhaps the most difficult issue in determining the effects of fatigue on performance is that of definition; fatigue can be conceptualized as muscular lactic acid concentrations, perceptual efficiency, willingness to accept risk, amount of sleep loss, etc. Research on the effects of fatigue has yielded scattered results, often illustrating a dissociation between external conditions expected to result in fatigue (e.g., sleep loss) and performance effectiveness. The study of fatigue effects in the maritime industries, and the development of potential mitigation strategies is compounded by the two classes of variable described above, i.e., sleep disruption and circadian rhythm variations. Related variables include incapacitation due to motion sickness and/or ingestion of alcohol or drugs. This section selectively reviews studies in these areas, focusing principally on fatigue.

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Colquhoun, W.P. (1985). Hours of work at sea: watchkeeping schedules, circadian rhythms and efficiency. Ergonomics, 28(4), 637-653.

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Citation

Bittner, A.C., Jr., & Guignard, J.C. (1988). Shipboard evaluation of motion sickness incidence. Trends in Ergonomics/Human Factors V, pp. 529-539.

Area(s) of Focus

Fatigue/Incapacitation

Mode/Industry

Maritime

Type of Paper

Empirical

Methodology

Field study

Issue Addressed

The nature and causes of motion sickness

Principal Finding

This study compared results of subjective questionnaires and ship motion. The results of this analysis showed that motion sickness is characterized by two functionally independent factors: 1) general motion illness; 2) retching and vomiting. General motion illness corresponded to vertical ship motion, while retching and vomiting corresponded to the transverse movement of the ship.

Deficiencies

Citation

Colquhoun, W.P. (1985). Hours of work at sea: watchkeeping schedules, circadian rhythms and efficiency. Ergonomics, 28(4), pp. 637-653.

Area(s) of Focus

Fatigue/Incapacitation

Mode/Industry

Maritime

Type of Paper

Review

Methodology

Issue Addressed

Type of watch rotation and physiological/psychological adaptation

Principal Finding

Reviews a variety of watch structures: stabilized 3 watch, rotating 3 watch, "close routines", "industrial routines", and 2-watch systems. Main findings are the apparent superiority of watch structures that permit an extended time-off period, e.g., 10-12 hours. Physiological rhythm appears to adapt best in these circumstances. Several studies illustrated a relationship between circadian variation in temperature and performance.

Deficiencies

Lack of studies documenting performance/physiology relation over time during adaptation period.

Citation

Colquhoun, W.P., Rutenfranz, J., Goethe, H., Neidhart, B., Condon, R., Plett, R., & Knauth, P. (1988). Work at sea: a study of sleep, and of circadian rhythms in physiological and psychological functions, in watchkeepers on merchant vessels: I. Watchkeeping on board ships: a methodological approach. Occupational and Environmental Health, 60, 321-329.

Area(s) of Focus

Fatigue/Incapacitation

Mode/Industry

Maritime

Type of Paper

Empirical

Methodology

Observation of longitudinal & trans-meridian journeys

Issue Addressed

Circadian disruption due to watchkeeping, time zone changes on high speed ships, and fly-in crews.

Principal Finding

The study examined the effects on performance, activity diary; oral temp, rectal temp, heart rate, performance on mental tests, urine samples, subjective state. It found that average sleep duration of watchkeepers was shorter than day workers. In addition, the 3rd Mate has lowest quality and amount of sleep. Sleep that onsets before midnight is best, followed by sleep after midnight, then day time sleep. Watchkeepers have no opportunity to compensate for sleep deficit because of no days off. The study proposed an extended watch system to permit longer sleep periods.

Deficiencies

Citation

Colquhoun, W.P., Watson, K.J., Gordon, D.S. (1987). A shipboard study of a four-crew rotating watchkeeping system. Ergonomics, 30(9), pp. 1341-1352.

Area(s) of Focus

Fatigue/Incapacitation

Mode/Industry

Maritime

Type of Paper

Empirical

Methodology

Temperature measurement and alertness ratings of crews on a 4-day rotating watch system.

Issue Addressed

Impact of fast watch rotation system on circadian rhythm.

Principal Finding

Four-day rotation did not cause phase shift as measured by temperature or subjective alertness. Alertness was always lowest at the beginning of a watch. Alertness was disrupted following night watches. A 6-hour, 4-crew fixed watch system is proposed as minimally disruptive of the sleep of most crew members.

Deficiencies

Measurements taken over a 4-day period. Perhaps a longer period would have illustrated phase shifts.

Citation

Condon, R., Colquhoun, W.P., Knauth, P., Plett, R., Neidhart, B., DeVol, D., Eickhoff, S., Rutenfranz, J. Work at sea: A study of sleep, and of circadian rhythms in physiological and psychological functions, in watchkeepers on merchant vessels - V. Effects of time zone crossings. Occupational and Environmental Health, 61, pp. 39-49.

Area(s) of Focus

Fatigue/Incapacitation

Mode/Industry

Maritime

Type of Paper

Empirical

Methodology

Body temperature, performance & subjective alertness measured every 4 hours from 15 4-on/8-off watchkeepers, and 28 day workers.

Issue Addressed

Alterations in circadian rhythms during transit across time zones and interactions with watchkeeping schedule.

Principal Finding

Physiological and psychological measures phase shift with time zone changes, there is no difference in rate of adaptation, but the daily pattern of variation in rhythmic functions differs on west vs. eastward journeys.

Deficiencies

Data pooling of watchkeepers and day workers may mask more complex rhythmic manifestations in watchkeepers.

Citation

Condon, R., Colquhoun, P., Plett, R., DeVol, D., & Fletcher, N. (1988). Work at sea: A study of sleep, and of circadian rhythms in physiological and psychological functions, in watchkeepers on merchant vessels - IV. Rhythms in performance and alertness. Occupational and Environmental Health, 60, 405-411.

Area(s) of Focus

Fatigue/Incapacitation

Mode/Industry

Maritime

Type of Paper

Empirical

Methodology

Measured subjective alertness, vector test and letter cancellation performance

Issue Addressed

Adaptation of performance

Principal Finding

Different watches showed performance curves that varied - analysis showed an interaction between watch group and time of day on performance; this indicates incomplete adaptation, since curves would otherwise be identical. While alertness declined just prior to sleep, performance did not.

Deficiencies

The intrusive nature of task performance probably resulted in task/alertness rating dissociation.

Citation

Connaughton, S.T. (February/March, 1988). Federal rules on operating a commercial vessel while intoxicated. Proceedings of the Marine Safety Council, 45(2), 40-43.

Area(s) of Focus

Fatigue/Incapacitation

Mode/Industry

Maritime

Type of Paper

Review

Methodology

Issue Addressed

Principal Finding

Reviews background and intent of CFR 33 Part 95 concerning vessel operation while intoxicated.

Deficiencies

Citation

Craig, A., & Condon, R. (1984). Operation efficiency and time of day. Human Factors, 26(2), 197-205.

Area(s) of Focus

Fatigue/Incapacitation

Mode/Industry

Maritime

Type of Paper

Empirical

Methodology

Test battery, paper & pencil tests of collision vector judgment, navigation plotting, signal identification, visual search, and letter cancellation exercises.

Issue Addressed

Performance across the day in 3-hour intervals.

Principal Finding

Most tasks improved in speed throughout the day, although accuracy decreased. Suggests need to evaluate criterion shifts as function of time of day.

Deficiencies

Because performance was obtained in six separate sessions, cannot really infer relation between performance and time of day. No control over subjects activities prior to test session. Need to measure performance over a continuous period.

Citation

ERGOSEA 81: The Second International Conference on Human Factors at Sea. Conference held October 5-8, 1981.

Area(s) of Focus

Fatigue/Incapacitation, manning

Mode/Industry

Maritime

Type of Paper

Empirical, review

Methodology

Literature review, surveys, interviews

Issue Addressed

Fatigue, manning, workload

Principal Finding

A number of papers at this conference stated that physiological and behavioral measures of fatigue are difficult to apply. However, they found self-report methods to be quite useful. In addition, they stated that organizational and design factors might reduce fatigue.

Deficiencies

The discussion of automation is weak, especially in specifying that automation should incorporate "ergonomic features."

The papers fail to make a clear distinction between mental workload and fatigue and their effects on "Inattention."

Citation

Fletcher, N., Colquhoun, W.P., Knauth, P., DeVol, D., Plett, R. (1988). Work at sea: A study of sleep, and of circadian rhythms in physiological and psychological functions, in watchkeepers on merchant vessels - VI. A sea trial of an alternative watchkeeping system for the merchant marine. Occupational and Environmental Health, 61, pp. 51-57.

Area(s) of Focus

Fatigue/Incapacitation

Mode/Industry

Maritime

Type of Paper

Empirical

Methodology

Field study - sleep logs, quality ratings and interviews

Issue Addressed

Impact of "close" watch system on length and quality of sleep, based on availability of a 10-12 hour free period.

Principal Finding

Sleep was longer on "close" system during sea passage than on harbor period. Third mate ranked sleep quality higher.

Deficiencies

Subjects used were veteran seafarers, very accustomed to 4-on, 8-off; 1st Mate could not adjust even after 15 days. Data aggregation made comparisons of sleep length and quality difficult, especially comparing open sea planes.

Citation

Low, A., Goethe, W.H.G., Rutenfranz, J., & Colquhoun, W.P., et al. (1987). Human factors: Effects of watchkeeping - results of studies for a German "ship of the future". Presented at 1987 Ship Operations, Management and Economics Interna ional Symposium, Kings Port, NY. Jersey City, NJ: The Society of Naval Architects and Marine Engineers.

Area(s) of Focus

Fatigue/Incapacitation

Mode/Industry

Maritime

Type of Paper

Empirical

Methodology

Survey of mariners; measurements of performance & physiological parameters

Issue Addressed

Need for alternative watchkeeping schedules

Principal Finding

The study found that most crew did not like the two watch system, most liked a 3 watch (90%) system. Their analysis showed that mariners' sleep periods are shorter than land-based workers, often broken into 2 periods. Examining physiological data, they found that Catecholamine secretion reflected shifts, but not temperature. Mental alertness remained related to time of day, did not adapt. The results of their analysis suggest that changing to a 6-2 system that would permit 10-14 hours of uninterrupted time to sleep.

Deficiencies

Citation

Pollard, J.K., Sussman, E.D., Stearns, M. (November 1990). Shipboard crew fatigue, safety and reduced manning (Final Report). (Report No. DOT-MA-RD-840-90014, DOT-VNTSC-MARAD-90-1). Cambridge, MA., Department of Transportation. NTIS, Springfield, VA.

Area(s) of Focus

Fatigue/Incapacitation, manning

Mode/Industry

Maritime

Type of Paper

Empirical

Methodology

Survey, observation, interview

Issue Addressed

Fatigue and workload

Principal Finding

This report found that overtime records are not an accurate reflection of workload, since union rules prescribe minimum hours for jobs. In addition, the crew "saw no point" and resisted completing the detailed task-time surveys. This result suggests that better workload/fatigue survey instrument needs to be developed. In addition, it recommends study of different responses by operators to OPA '90 work rule.

Deficiencies

This study uses antiquated concept of "inattention" that confounds fatigue, mental workload, and inattention. These can be dissociated experimentally, and would lead to more informative results that could determine task types/conditions leading to error. This study also fails to consider workload transition periods. It also makes no attempt to relate workload or fatigue to impact on different types of tasks, i.e., which task would become more error prone with increasing fatigue.

Citation

Torsvall, L., Castenfors, K., Akerstedt, T., & Froberg, J. (1987). Sleep at sea: A diary study of the effects of unattended machinery space watch duty. Ergonomics, 30(9), pp. 1335-1340.

Area(s) of Focus

Fatigue/Incapacitation

Mode/Industry

Maritime

Type of Paper

Empirical

Methodology

Field study using a diary and sleep log

Issue Addressed

Effect of "on call" system on sleep of engineers.

Principal Finding

The paper generated several conclusions:

When on call and alarms occur, sleep length is reduced.
When on call, sleep onset is reduced, even with no alarms.
When on call and no alarms, sleep quality is reduced - attributed to "anticipatory" stress
No effect related to accumulation of on call duty over time.

Deficiencies

No control group

MANNING

Changes in technology together with increased economic pressures have led to changes in the staffing level and organization onboard ships. The future promises more radical changes as the technological sophistication and economic pressure increases. Because of the high consequences of accidents the Coast Guard cannot afford to let companies implement these changes without knowing the implications of staffing changes on the safety of ships. A manning model provides economically feasible, unbiased, rational basis for evaluating the safety implications of changes in shipboard manning.

A number of modeling techniques have already been developed for the marine industry, and many others have been developed for a variety domains such as commercial and military aircraft, military command and control, weapon systems, chemical processing, manufacturing, and nuclear power plants. While these techniques do not all address the specific issues involved with shipboard manning, they illustrate the feasibility of modeling techniques. This section presents a compilation of references pertinent to the issue of maritime manning models.

Reference List - Manning

Beetham, E.H. (1989, February). Bridge manning. Seaways, pp. 3-7.

Booher, H.R., & Hewitt, G.M. (1990). Manprint tools and techniques. In H.R. Booher (Ed.), MANPRINT: An approach to systems integration pp. 343-390. New York: Van Nostrand Reinhold.

Connaughton, S.T. (1987). Coast Guard Merchant Vessel Manning, No. 10. Proceedings of 1987 Ship Operations, management and Economics International Symposium, Kings Point, New York, September 17-18, 1987 (pp. 10-1-10-7).

Dutton, J.M., & Starbuck, W.H. (1971). Computer simulation models of human behavior: A history of an intellectual technology. IEEE Transactions on Systems, Man, and Cybernetics, SMC - 1 2.

Gaffney, M.E. (1987). Reduced manning in the liner trades: Technological capabilities and organizational implications. Washington, DC: National Academy of Sciences, Maritime Transportation Research Board.

Gaffney, M.E. (1989, June 6). Effective manning at American President Lines. (Cooperative Agreement No. MA-11727, Report No. MA-RD-840-89008). Oakland, CA: American President Lines, Ltd.

Harris, R., Iavecchia, H.P. & Dick, A.O. (1989). The human operator simulator (HOS-IV). In G.R. McMillan, D. Beevis, E. Salas, M.H. Strub, R. Sutton, & L. van Breda (Eds.), Applications of human performance models to system design (pp. 275-280). New York: Plenum Press.

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Kirkpatrick, M., Malone, T.B., & Andrews, P.J. (1984). Development of an interactive microprocessor based workload evaluation model (SIMWAM). Proceedings of the Human Factors Society - 28th Annual Meeting (pp. 78-80).

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Malone, T.B., Baker, C.C. Permenter, K.E. (Unpublished contractor's report). The role of human engineering in ship manning reduction. Carlow Associates, Inc.

Malone, T.B., Kirkpatrick, M., & Kopp, W.H. (1986). Human factors engineering impact on system workload and manning levels. Proceedings of the Human Factors Society - 30th Annual Meeting (pp. 763-767).

Maritime Administration, Office of Research and Development/Advanced Ship Operations. (1983). Crew rationalization study, ODS line vessels (Draft). Washington, DC: U.S. Department of Commerce.

McCallum, M.C. & Underwood, J.A. (1991). Impact of automation on command and control information processing. Prepared for Presentation to the 59th MORS Symposium.

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Palmer, P.S.A. (1991). A closer look at licensing. Proceedings of the Marine Safety Council, September-October, 1991 (pp.6-8).

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Pew, R.W., & Baron, S. (1983). Perspectives on human modelling. Automatica, 19(6), 663-676.

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Stassen, H.G., Kok, J.J., Veldt, R.V.D., & Heslinga, G. (1985). Modelling human operator performance, possibilities and limitations. IFAC Man-Machine Systems, pp. 141-146. Varese, Italy.

Wiehagen, W.J., Brnich, M.J., Kellner, H.J, & Lacefield, W.E. (1998). The work crew performance model: Linking training, assessment, and performance. Information Circular - U.S. Bureau of Mines, 9185, pp. 15-22.

Yamanaka, K. & Gaffney, M. (1987). Effective manning in the orient: A review of Asian developments. (Report No. MA-RD-770-87052). Washington, DC: U.S. Department of Transportation, Maritime Administration.

Citation

Beetham, E.H. (1989, February). Bridge manning. Seaways, pp. 3-7.

Area(s) of Focus

Manning, navigation

Mode/Industry

Maritime

Type of Paper

Commentary

Methodology

Results of committee discussion

Issue Addressed

Manning of the bridge

Principal Finding

The paper concludes that one-man bridge operation is not sufficient to maintain safe operation of a vessel. Factors that should be included in the analysis of one-man bridge operation include: crew casualties, adverse situations at sea, ship design, operational aspects, human factors, sensor reliability.

Deficiencies

The detailed statistics of vessel losses and incidents do not relate in a coherent way to the issue of manning the bridge. Moreover, aside from detailed accident statistics, other areas considered only superficially.

Citation

Booher, H.R., & Hewitt, G.M. (1990). Manprint tools and techniques. In H.R. Booher (Ed.), MANPRINT: An approach to systems integration, pp. 343-390. New York: Van Nostrand Reinhold.

Area(s) of Focus

Manning

Mode/Industry

Military

Type of Paper

Review

Methodology

Issue Addressed

Human performance, anthropometric, and manning models and tools

Principal Finding

This paper provides a catalog of tools and techniques to support analytic and empirical system evaluation. Domains covered include human factors, manpower personnel and training (MPT), safety and health hazards. Manning models include both micro and macro levels.

Deficiencies

Many of the models discussed are developed for military and the aerospace industry and applicability to the maritime industry may be limited.

Citation

S. Connaughton. (1987). Coast Guard Merchant Vessel Manning, No. 10. In Proceedings of 1987 Ship Operations, Management and Economics International Symposium, Kings Point, New York, September 17-18, 1987 (pp. 10-1-10-7).

Area(s) of Focus

Manning

Mode/Industry

Maritime

Type of Paper

Methodology

Issue Addressed

The role of the Coast Guard in determining minimum manning.

Principal Finding

Until recently the Coast Guard has specified manning levels far below the industry standards. Recent advances in automation and increased competition have led companies to question Coast Guard recommendations. This paper presents a detailed overview of how the Coast Guard assigns manning levels. In particular, this paper enumerates the potential concerns and processes associated with reductions in deck, engine, and maintenance departments. The report also mentions statutory constraints, such as limits on interdepartmental crossover, that limit the Coast Guard's authority to revise or create new manning configurations.

Deficiencies

Citation

Dutton, J.M., & Starbuck, W.H. (1971). Computer simulation models of human behavior: A history of an intellectual technology. IEEE Transactions on Systems, Man, and Cybernetics, SMC - 1 2

Area(s) of Focus

Manning

Mode/Industry

Type of Paper

Review

Methodology

Annotated bibliography

Issue Addressed

Models of human performance

Principal Finding

This paper includes an annotated bibliography that classifies 2024 studies published before 1971.

The models developed in these studies fall into one of four categories: 1) individuals; 2) individuals who interact; 3) individuals who aggregate; 4) individuals who aggregate and interact. These models were also classed in terms of data used for its creation and validation. This review illustrates potential strategies that might be adopted to create a manning model.

Deficiencies

Citation

Gaffney, M.E. (1987). Reduced manning in the liner trades: Technological capabilities and organizational implications. Washington, DC:National Academy of Sciences, Maritime Transportation Research Board.

Area(s) of Focus

Manning

Mode/Industry

Maritime

Type of Paper

Commentary

Methodology

Issue Addressed

Survey of technological and organizational changes that have accompanied reduced manning.

Principal Finding

The study begins with a description of the changes in automation that have facilitated reductions in manning. Following this description, the paper presents a review of some of the organizational factors affecting manning. These factors include polyvalent officers, matrix manning, and increased shore-side support. The report concludes with an analysis of European and Japanese manning structures, illustrating how both automation and organizational change have led to manning reductions.

Deficiencies

Citation

Gaffney, M.E. (1989, June 6). Effective manning at American President Lines. (Cooperative Agreement No. MA-11727, Report No. MA-RD-840-89008). Oakland, CA: American President Lines, Ltd.

Area(s) of Focus

Manning

Mode/Industry

Maritime

Type of Paper

Commentary, empirical

Methodology

Field study, structured interviews

Issue Addressed

Effective manning and the effect of technological and organizational change.

Principal Finding

The report addresses four primary issues: 1) Manning reduction; 2) Employee participation; 3) Work redesign - job flexibility prevents overload; 4) Social integration - changing technology has effect not only on work, but also on leisure activity. By examining ship manning through these broad areas this report provides insight into the organizational factors that influence ship safety.

Deficiencies

The data represented in this report came from a small sample of ships and the conclusions may not be valid for others.

Because this report focussed on management and organizational issues and failed to consider more basic human factors issues.

Citation

Harris, R., Iavecchia, H.P., & Dick, A.O. (1989). The human operator simulator (HOS-IV).

Area(s) of Focus

Manning

Mode/Industry

Military

Type of Paper

Review

Methodology

Human performance simulation

Issue Addressed

Development of a model of human performance

Principal Finding

This paper describes a method for developing a model that generates system behavior based on models of the machine system, the environment and the human. This model depends on micromodels of human performance that determine task time and success or failure as a function of environmental and interface conditions.

Deficiencies

HOS may be best suited to guiding design decisions that influence displays. Other modeling techniques may be more appropriate for manning decisions.

Citation

Istance, H. (1987). Human factors issues in advanced bridge systems. Presented at the Third International Conference on Bridge Design and Ship Operation. Oslo, Norway.

Area(s) of Focus

Manning, navigation, automation

Mode/Industry

Maritime

Type of Paper

Review, commentary

Methodology

Issue Addressed

One-man bridge and centralized ship control center.

Principal Finding

This paper concludes that one-man operation is technically feasible, but developing and maintaining all required skills will be difficult. With advances in technology, the operator's role will change and the model of "supervisory control" used in a process control industry may help identify and solve problems of the marine industry.

Deficiencies

Somewhat disjointed and superficial description of problem and solution. The authors point to general problems but offer little specific advice for solutions.

Citation

Kim, I.S. (1986). Experimental design of multi-crewing in R.O.K. Navy. Master's Thesis, Naval Postgraduate School.

Area(s) of Focus

Manning

Mode/Industry

Maritime, military

Type of Paper

Review, theoretical

Methodology

Issue Addressed

Evaluation of the strengths and weaknesses of multi-crew systems.

Principal Finding

This paper examines cost and efficiency of single and multiple crew ships and found that multiple crew systems were more productive than single crew systems. Makes a distinction between incommensurable and commensurable measures. In addition, it examines different types of manning configurations and their implications for qualitative and quantitative aspects of shipboard life.

Deficiencies

Citation

King, John. (1980). Modern technology and the manning of merchant ships. In J. Vlietstra (Ed.), Ship Operation Automation, III (pp. 27-30). New York: North Holland.

Area(s) of Focus

Manning, automation

Mode/Industry

Maritime

Type of Paper

Commentary

Methodology

Issue Addressed

The effect of new technology on manning requirements.

Principal Finding

This paper argues that many of the maritime industry's long established practices may require reevaluation as technological advances are introduced. The authors argue that while advanced technology replaces some of the seafarer's jobs, it may introduce other tasks. For example, incorporating personal computers into ships provides ship personnel with the ability to attend to many management functions reserved for shore-side personnel. With careful introduction of new technology, seafarer's roles may be enriched.

Deficiencies

Citation

Kirkpatrick, M., Malone, T.B., & Andrews, P.J. (1984). Development of an interactive microprocessor based workload evaluation model (SIMWAM). Proceedings of the Human Factors Society - 28th Annual Meeting (pp. 78-80).

Area(s) of Focus

Manning

Mode/Industry

Maritime, military

Type of Paper

Model development

Methodology

Task network simulation

Issue Addressed

Description of the development of SIMWAM to evaluate workload and manning

Principal Finding

The paper begins with a comparison of WAM and SAINT modeling tools and found both to be deficient. WAM was purely deterministic task sequences; SAINT lacked the ability to model the interruption of low priority tasks with high priority tasks. The authors describe SIMWAM as an alternative that alleviates both of these limitations.

Deficiencies

The review of the modeling techniques included only a few examples.

Citation

Knudsen, Ragnar Kr. and Mathiesen, Tor-Chr. (1987). Operational safety and minimum manning No. 27. In Proceedings of 1987 Ship Operations, Managements and Economics International Symposium, Kings Point, New York, September 17-18, 1987 (pp. 27-1-27-10).

Area(s) of Focus

Manning

Mode/Industry

Maritime

Type of Paper

Commentary

Methodology

Issue Addressed

Manning reductions and safety.

Principal Finding

The study points out that the manning level required will always depend upon the number of different functions that are to be carried out under specific operational conditions. The paper outlines a method to evaluate manpower requirements. This method consists of a description of a process that involves specifying functions and manpower requirements for those functions, based on operational conditions.

Deficiencies

The paper fails to provide anything but a very abstract direction towards a model that could be used to specify manning requirements.

Citation

Linton, P.M., Plamondon, B.D., Dick, A.O., Bittner, A.C., Jr., & Christ, R.E. (1989). Operator workload for military system acquisition. Unpublished manuscript.

Area(s) of Focus

Manning

Mode/Industry

Military

Type of Paper

Review

Methodology

Issue Addressed

Comparison of models and classes of models used to estimate operator workload.

Principal Finding

This paper presents three general types of workload evaluation tools: math models, timeline/task analysis, and simulation. The task analysis illustrates operator performance requirements against a fixed scenario background, while simulation techniques represent operator behavior within the system. This enables a simulation to produce measures of operator workload and system performance.

Deficiencies

Concentrates on workload and does not address its relation to manning.

Citation

Levison, W.H. (1989). The optimal control model for manually controlled systems.

Area(s) of Focus

Manning

Mode/Industry

Aviation

Type of Paper

Review

Methodology

Issue Addressed

The use of optimal control theory for modeling humans

Principal Finding

This paper describes the limits and capabilities of optimal control theory (OCM). These limits include the requirement that all external inputs to be statistically stationary and all dynamic response elements to be linear. In addition, OCM requires that performance objectives be represented by a quadratic performance index. One of the major benefits of OCM is that it accommodates multiple inputs and outputs, unlike classical control theory that accounts for only single inputs and single outputs.

Deficiencies

Method imposes severe requirements on the specification of the operators tasks. For example, OCM requires only linear equations to be used to describe the control task. Therefore, many actual systems may not fit into the OCM framework. In addition, the complexity of this formalism entails substantial investment for model development. So simpler techniques may provide more economical answers.

Citation

Malone, T.B., Baker, C.C., Permenter, K.E. (unpublished manuscript). The role of human engineering in ship manning reduction. Carlow Associates Inc.

Area(s) of Focus

Manning

Mode/Industry

Military/Marine

Type of Paper

Review theoretical

Methodology

Theoretical discussion of human factors methods and design

Issue Addressed

Reduction of manning requirements by including human factors in design

Principal Finding

This paper identified the basis of manning requirements as a measure of the workload associated with the roles of humans in system operations. Human engineering techniques to minimize workload include: application of design principles, task simplifications, and decision aiding. One of the prime concerns with each of these technologies is to identify human role regardless of the extent of automation.

Deficiencies

Citation

Malone, T.B., Kirkpatrick, M., & Kopp, W.H. (1986). Human factors engineering impact on system workload and manning levels. Proceedings of the Human Factors Society - 30th Annual Meeting. (pp. 763-767).

Area(s) of Focus

Manning

Mode/Industry

Military/Maritime

Type of Paper

Model development

Methodology

Task network simulation

Issue Addressed

Simulate the effect of technological innovation on manning level and workload on an aircraft carrier

Principal Finding

Task network simulation was successful in anticipating effects of automation, and proved useful in reducing workload. This effort demonstrates the potential of models to provide estimates of manning requirements.

Deficiencies

Citation

Maritime Administration, Office of Research and Development/Advanced Ship Operations. (1983). Crew rationalization study, ODS liner vessels (Draft). Washington, DC:U.S. Department of Commerce.

Area(s) of Focus

Manning

Mode/Industry

Maritime

Type of Paper

Model development

Methodology

Multiple activity chart analysis

Issue Addressed

Addressed feasibility of ship manning and crew structures applicable to U.S.-flagged ships built after 1960 and before 1970.

Principal Finding

This study addressed three types of vessels. It developed potential crew structures based on functional requirements and engineering system requirements. It also analyzed both normal operating conditions and a variety of emergency scenarios.

Deficiencies

While the functional analysis and data gathered by this study provides a strong basis for manning evaluation, the multiple activity charts fail to provide a quantitative analysis of crew workload.

Citation

McCallum, M.C., & Underwood, J.A. (1991). Impact of automation on command and control information processing. Prepared for Presentation to the 59th MORS Symposium.

Area(s) of Focus

Manning

Mode/Industry

Military

Type of Paper

Model development

Methodology

Spreadsheet aggregation of time estimates

Issue Addressed

This paper addresses the effect of automation on effectiveness of command and control centers.

Principal Finding

Findings suggest that a spreadsheet-based analysis provides valuable insight into how automation may influence system performance. In particular, the analysis shows how implementing automation will affect the performance of a military command and control center.

Deficiencies

One of the primary limits of this model lies in the fact that it simply sums task times across individuals, neglecting time-dependent workload peaks and dynamic changes in information requirements.

Citation

Melber, B.D., Berk, B., Olson, J., & Tunestam, B. (1983). An international comparison of manpower and staffing regulation and practice in commercial nuclear power plants. (Contract FIN #B2360) Division of Human Factors Safety, Office of Nuclear Reactor Regulations, U.S. Nuclear Regulatory Commission NUREG/CR-2953, PNL-4469. Seattle: Battelle Human Affairs Research Centers

Area(s) of Focus

Manning

Mode/Industry

Nuclear

Type of Paper

Review

Methodology

Issue Addressed

Analysis of the regulatory structures to determine the basis of manning and experience requirements in the nuclear industry around the world

Principal Finding

The papers' findings were prefaced by the statement: "While it can be constructive to consider other approaches, the different context of other countries need careful delineation if any given practice is attempted in the United States." (pg. 4) From an analysis of staffing practices around the world the study found five criteria used for manning determinations:

1. Manning decisions begin top-down, with model of organizational structure
2. Must consider other factors: unionization, labor laws
3. Investigate manpower needs over time
4. Often driven by an empirical basis with annual reviews guiding staffing decisions
5. Use of prior experience with fossil fueled plants as a basis of decisions.

Deficiencies

Citation

Nautical Institute on Improving Standards of Bridge Operations. (1989, February). Recommendations by Council, December 1988. Seaways, p. 9.

Area(s) of Focus

Manning, automation

Mode/Industry

Type of Paper

Commentary

Methodology

Issue Addressed

Improve effectiveness of bridge operations and evaluate one-man bridge operation.

Principal Finding

The report consists of a listing of guidance spanning four areas: keep systems under review; ensure plotting; check lists; and watchkeepers record book.

Deficiencies

Citation

Palmer, P. S. A. (1991). "A closer look at licensing." Proceedings of the Marine Safety Council, September-October 1991, pp. 6-8.

Area(s) of Focus

Manning, training

Mode/Industry

Maritime

Type of Paper

Review

Methodology

Issue Addressed

Describes planned study of mariner licensing improvements.

Principal Finding

Licensing is basically statutory; CG has no procedures to determine amount and availability of training during sea service. No practical testing has been done. Refresher training after absence is not currently required. The paper reports increasing industry support for mandatory practical training, especially related to automation and Hazops. Proposed CG study would review deck and engine department functions, determine Hazops and special training needs. Also, this report suggests the need to evaluate costs.

Deficiencies

This study was not funded by USCG. The proposed methodology relies heavily on regulation review and interviews with shipboard personnel and maritime training/industry personnel. This method could be improved with the addition of observational techniques, cognitive task analysis, and linkage to training development via the ISD process. Such a study needs to be done.

Citation

Perdok, J. (1984). Methods to study mental workload in one man manning situations. Paper presented at the Second International Bridge Design and Operation Forum.

Area(s) of Focus

Manning, navigation

Mode/Industry

Maritime

Type of Paper

Empirical

Methodology

Simulator experiment

Issue Addressed

Mental workload and the effects of new technology

Principal Finding

This study tested the effects of bad visibility and traffic density on the ability of a single person to control the ship. The dependent measures included: ship performance, subjective ratings, heart rate, and a "danger function". The results show a correlation between subjective ratings of effort and ship performance (the "danger function" and the deviation from specified course).

Deficiencies

The study fails to mention the relationship between heart rate, or heart rate variability, and the other measures of workload. In general, this study fails to give good guidance for selecting measures of mental workload.

Citation

Perse, R.M., Baker, C.C., Malone, T.B. (1990). Simulation analysis of human task loading for US Navy surface combatant damage control organizations. (Prime Contract No. N00024-85-D-4373). Naval Sea Systems Command.

Area(s) of Focus

Manning

Mode/Industry

Maritime, military

Type of Paper

Model development

Methodology

Task network simulation

Issue Addressed

Used simulation model to evaluate overall workload and individual workload during damage control

Principal Finding

The study developed a simulation of Navy damage control teams. The output of this simulation provides data concerning operator workload, that can be used to guide the development of human-machine interface.

Deficiencies

Since the simulation depends on Navy doctrine it may not provide an accurate representation of operator's true behavior. A similar problem may exist in developing maritime Manning models. With these potential models, company policy may not be an accurate reflection of actual work behavior.

Citation

Perse, R.M., Callahan, K.P., & Malone, T.B. (Unpublished technical report) ISMS human engineering development of a task model and analytical tool. Final Technical Report. (Prime Contract Number N00024-85-D-4373). Naval Sea Systems Command,

Area(s) of Focus

Manning

Mode/Industry

Maritime, military

Type of Paper

Model development

Methodology

Task network simulation

Issue Addressed

Effect of automation

Principal Finding

Found that a model of information processing and decision making was useful for anticipating the effectiveness of a damage control center on naval ships.

Deficiencies

Validation only by comparison of time history of model output to task flowcharts.

Citation

Pew, R.W., & Baron, S. (1983). Perspectives on human performance modelling. Automatica, 19(6), pp. 663-676. Great Britain: Pergamon Press.

Area(s) of Focus

Manning

Mode/Industry

Type of Paper

Review

Methodology

Simulation

Issue Addressed

Review of psychological and control theoretic approaches to modeling systems.

Principal Finding

This paper discusses modelling as an iterative procedure consisting of: 1) task analysis; 2) modeling and prediction; 3) simulation and test; 4) development of functional specifications. In many cases the success of a model depends on the constraints available in the environment. Optimal control model (OCM) has been a very successful model in the domain of continuous control, primarily because the operator's activity depends on a goal driven adaptation to the environment. PROCRU (Procedure Oriented Crew model) integrates artificial intelligence, task network and OCM to produce a complex representation of the human-machine system.

Deficiencies

Citation

PRC. (1992). Mid-term sealift ship technology development program. Task 1.5 Assessment of Advanced Manning Techniques. (Interim projection of manning levels final report).

Area(s) of Focus

Manning

Mode/Industry

Maritime

Type of Paper

Commentary, model development

Methodology

Issue Addressed

The impact of technological changes on manning requirements

Principal Finding

This paper draws a distinction between manpower (theoretical crew required) and manning level (actual crew size determined by various regulations and traditions).
Manpower is not tied to ship size, cargo or speed, but is dependent on other characteristics such as automation, reliability, service route. Based on increased automation, crew size can be reduced according to an automation/technology and manpower matrix that they provide.

Deficiencies

The hypothetical manning requirements, produced by the manpower matrix, have little supporting evidence. Additionally, the report fails to discuss the assumptions and limits of the modeling approach they have chosen.

Citation

Rouse, William B. and Reid, Robert E. (1981). An approach to analysis of human-computer interaction in ship control. In Proceedings of Sixth Ship Control Systems Symposium, October 26-30, 1981, Vol.2. (pp. E1 3-1-6).

Area(s) of Focus

Manning, automation, navigation

Mode/Industry

Maritime

Type of Paper

Theoretical, review

Methodology

Queuing theory

Issue Addressed

An analytic method of allocating human and automatic control.

Principal Finding

This paper argues that much of the use of automation in the maritime industry has been in a "bottom-up" manner, emphasizing particular control functions. To make effective use of technology, a "top-down" approach might be helpful. A "top-down" approach would define what should be automated, rather than what can be automated. By stating the problem in terms of total automation, either complete manual or complete automatic controls, a powerful formalism, queuing theory, can be employed to predict system performance.

Deficiencies

Although the "top-down" approach offers many advantages, the dichotomy of automatic/manual control may not accurately represent the situation. Many maritime systems represent instances of partial automation.

Citation

Sablowski, N., & Froese, J. (1987). Workload measurement on a simulated ship's bridge. Proceedings of the International Conference on Marine Simulation. pp. 254-261.

Area(s) of Focus

Manning, automation

Mode/Industry

Maritime

Type of Paper

Empirical

Methodology

Simulator study using workload measures

Issue Addressed

Limits of one-man manning of conventional and advanced bridges

Principal Finding

This study manipulated workload by varying: 1) instrument failures, risks of collision; 2) day/night travel; 3) manning; 4) instrumentation. The measures of workload included: primary task, secondary task, physiological, subjective ratings.
Workload measures seem to correspond to each other as well as the assumed difficulty of the task.

Deficiencies

The primary deficiency of this study was the lack of quantitative analysis, only a qualitative comparison of measures was presented. In addition, the study failed to include a description of the effects of manning or bridge design on workload.

Citation

Ship Analytics, Inc. (1987, February). Shipboard productivity methods, 3. (Report No. MA-RD-770-87004). USDOT

Area(s) of Focus

Manning

Mode/Industry

Maritime

Type of Paper

Job/task analysis

Methodology

Interviews/observations

Issue Addressed

Manning assignments and responsibilities on ships.

Principal Finding

The task description of various jobs do not match what actually occurs on a cargo ship. Work on ships was found to be inadequately planned, and utilized inefficient methods when better were known. This was particularly true of deck maintenance tasks.

Deficiencies

The job descriptions were produced from interview data collected from a single individual in each category. The interviewees perceptual biases crept in. Shipboard observations were conducted on two ships from the same company.

Citation

Siegel, A. & Lautman, M. (1974). A model for predicting integrated man-machine systems reliability. Naval Sea Systems Command

Area(s) of Focus

Manning

Mode/Industry

Maritime/military

Type of Paper

Model development

Methodology

Task network simulation

Issue Addressed

Integration of human reliability with equipment reliability.

Principal Finding

This study demonstrated how crew size, combined with environmental factors, interacted with the system to produce different levels of performance. The authors state that, "Social and work situations contain considerable random variation and such variation must be represented in any productive technique which is concerned with these situations." (pg. 107).

Deficiencies

Citation

Siegel, A.I., & Wolf, J.J. (1961, March). A technique for evaluating man-machine system designs. Human Factors, pp. 18-28.

Area(s) of Focus

Manning

Mode/Industry

Military

Type of Paper

Model development

Methodology

Task network simulation

Issue Addressed

Feasibility of computer-based simulation as a predictive tool to aid in system design

Principal Finding

This paper proposes a method to evaluate single operator systems before they are actually produced. Through computer-based simulation, they generated predictions that demonstrated the utility of these types of models. More specifically, this model incorporated time stress based on the number of tasks to be completed and the time required to complete them. This time stress affects the probability of failing to execute tasks correctly.

Deficiencies

The primary limit of this model lies in its inability to model multi-operator situations. However, the general concept could be extended to include these types of situations.

Citation

Stassen, H.G. (1989). On the modeling of manual control tasks. In G.R. McMillan, D. Beevis, E. Salas, M.H. Strub, R. Sutton, & L. van Breda (Eds.), Applications of human performance models to system design, pp. 107-122. New York: Plenum Press.

Area(s) of Focus

Manning

Mode/Industry

Type of Paper

Review

Methodology

Simulation

Issue Addressed

Models of human behavior

Principal Finding

The paper describes potential models in terms of modeling skills, rule or knowledge-based behavior. Skill-based behavior has been successfully modeled using classical and optimal control theory and analytic methods. Ruler-based performance has been modeled with approaches such as PROCRU; however, knowledge-based behavior has not been successfully modeled.

Deficiencies

Citation

Stassen, H.G., Kok, J.J., Veldt, R.v.d., & Heslinga, G. (1985). Modelling human operator performance, possibilities and limitations. IFAC Man-Machine Systems, pp. 141-146. Varese, Italy.

Area(s) of Focus

Manning

Mode/Industry

Process control

Type of Paper

Review

Methodology

Issue Addressed

The conditions under which human performance modeling might be successful.

Principal Finding

The paper concludes that only for those tasks which are well defined can modelling of human supervisory control be successful. Poorly defined areas like knowledge-based performance must be modeled with a normative technique or with a global perspective. Models that describe well defined task sequences are much easier to create and validate.

Deficiencies

Describes modelling in the context of design and not manning.

Citation

Wiehagen, W.J., Brnich, M.J., Kellner, H.J., Lacefield, W.E. (1988). The work crew performance model: Linking training, assessment, and performance. Information Circular - U.S. Bureau of Mines, 9185, pp. 15-22.

Area(s) of Focus

Manning, training

Mode/Industry

Mining

Type of Paper

Model development

Methodology

Simulation

Issue Addressed

Model and combine individuals' performance to produce estimates of overall organizational performance as a means of evaluating training programs.

Principal Finding

The study found that implementing a model should include provisions for:
Job/task determination
Observational analysis to establish performance baseline
Cost linkages between performance and costs
Intervention strategies
The general conclusions of this paper could be applicable to developing manning models for the maritime industry.

Deficiencies

Provides only cursory guidance on how data for failure probabilities might be derived.

Citation

Yamanaka, K., & Gaffney, M. (1987). Effective manning in the orient: A review of Asian developments. (Report No. MA-RD-770-87052). USDOT, Maritime Administration.

Area(s) of Focus

Manning, organizational

Mode/Industry

Maritime

Type of Paper

Commentary, field study

Methodology

Trip report

Issue Addressed

Reasons, environment, process and content of change of manning

Principal Finding

This paper examines manning level, job integration, social integration, and equipment layout. It found that integrated job descriptions are crucial for keeping workload down on modern ships. In addition, they found that technology alone does not drive manning levels; organizational factors play a major role. A comparison of reduced manning on modern vessels to standard crews show no increase in casualties, injury or illness.

Deficiencies

The Asian environment is very different compared to the U.S. environment and it is not clear how they compare. Also, it is unclear how reduced manning affects emergency response capabilities. As a descriptive text resembling a "trip report", it leaves large gaps regarding the effectiveness of the manning levels it evaluates.

NAVIGATION

Navigation is a critical task in shipping safety, and involves extensive human activity, which is increasingly facilitated with automation. Advances in radar, ARPA and now electronic charts promise to provide more precise navigational information, with potential for integrating with ship controls. While some studies show decreased mental workload and fewer accidents in simulations, there is a tendency toward "riskier" ship handling associated with automation. This section reviews articles describing the potential costs and benefits of advanced navigational automation.

Reference List

Agnew, H.J., Wooley, R.K. & Parfitt, G. (1989). The navigator's yeoman. Journal of Navigation, 42(2), 268-277.

Breedveld, D. (1988). Radar simulation training for inland waterway shipping. Journal of Navigation, 41(1), 25-34.

Froese, J. & Heinecke, A.M. (1984). An attempt to integrate information on a multi-colour display. Second International Bridge Design & Operation Forum.

Gardenier, J.S. (1981). Ship navigational failure detections and diagnosis. U.S. Coast Guard (G-DMT-1/54). Washington, D.C.

Goradia, D. (1989). Navigation with an integrated bridge. Shipbuilding Technology, Int., pp. 278-279.

Grabowski, M. (1989). Decision aiding technology and integrated bridge design. Presented at the Society of Naval Architects and Marine Engineers Spring Meeting/STAR Symposium, New Orleans, LA.

Habberley, J.S. & Taylor, D.H. (1989). Simulated collision avoidance maneuvers: a parametric study. Journal of Navigation, 42(2), 248-254.

Hadley, M.A. (1988). Present trends in naval bridge design and integrated navigation. Journal of Navigation, 41(2), 276-287.

Harumasa, H. & Kawashima, S. (1989). The super-rationalized bridge. Shipbuilding Technology Int., pp. 280-282.

Hayes, J. & Wald, E.D. (1980). Effectiveness of three electronic systems as collision-avoidance and grounding-avoidance aids: A simulator investigation in a congested harbor. (CAORF Report No. 13-7811-01). Kings Point, NY: National Maritime Research Center. (NTIS No. PB82-172073). Springfield, VA.

Ibbetson, E.R. (1988). Civil marine radar colour display. Journal of Navigation, 41(2), 256-260.

International Maritime Organization. (1991, December). Improved design and construction standards for bulk carriers: Computer-aided navigation system for safety (CAN). Submitted by Japan to the Sub-Committee on Ship Design and Equipment, 35th session, agenda item 24. (DE 35/INF.4).

Larsen, Capt. Per. (1987, October). Overall system reliability standards for one-man bridge operation. Presented at the Third International Conference on Bridge Design and Ship Operation. Paper Series No.:87 P012. Oslo, Norway.

Maybourn, R. (1987). The Navigator - man or machine? Journal of Navigation, 40(3), 334-343.

Moskvin, G.I., & Sorochinsky, V.A. (1988). Integrated navigation and electronic chart display systems. Journal of Navigation, 41(2), 295-299.

Plumridge, M.J.M. (1987, October). What electronic chart display do mariners want in 1990? Seaways, pp. 5-6.

Reynolds, J. (1984). Research into the use of VDU's on the bridge of tomorrow. Proceedings of the Second International Bridge Design and Operation Forum.

Rogoff, M. (1990-91, Winter). Electronic charts in the nineties. Journal of the Institute of Navigation, 37(4), 305-318.

Rossano, M.J., & Warren, D.H. (1989). Misaligned maps lead to predictable errors. Perception, 18, 215-229.

Schudlich, D. (1990). Integrated ship management and control. Shipbuilding Technology, pp. 177-178.

Schuffel, H., Boer, J.P.A., & van Breda, L. (1988). The ship's wheelhouse of the nineties: the navigation performance and mental workload of the officer of the watch. Journal of Navigation, 42(1), 60-72.

Stoop, J. (1990). Redesign of bridge layout and equipment for shipping vessels. Journal of Na vigation, 43(2), 215-228.

van Opstal, L.H. (1998). Standardization of electronic charts. Journal of Navigation, 41(2), 288-294.

Veldhuyzen, W., & Stassen, H.G. (1977). The internal model concept: An application to modeling human control of large ships. Human Factors, 19(4), 367-380.

Citation

Agnew, H.J., Woolley, R.K., & Parfitt, G. (1989). The navigator's yeoman. Journal of Navigation, 42(2), pp. 268-277.

Area(s) of Focus

Navigation

Mode/Industry

Maritime

Type of Paper

Commentary

Methodology

Issue Addressed

Potential pitfalls in the transition from paper-based charts to ECDIS

Principal Finding

Because of limits of electronic charts, including a lack of databases and supporting infrastructure, the authors claim that electronic chair displays may not be the most effective solution to maritime navigation.

Other possible problems of ECDIS include: 1) added tasks in traditional system: the route is both planned and displayed on chart, the ECDIS adds the planning stage to navigator's task; 2) gross errors may be missed because users loose the "feel" for reasonable course and positions.

The "Navigators' Yeoman" provides a potential solution to these problems. As a mechanical course plotting device that operates on a conventional chart, it allows navigators to retain the paper-based chart, while availing the navigators to some of the benefits of ECDIS.

Deficiencies

While this paper provides a good review of potential problems with ECDIS, it provides no empirical testing to support these claims.

Citation

Breedveld, D. (1988). Radar simulation training for inland waterway shipping. Journal of Navigation, 41(1), pp. 25-34.

Area(s) of Focus

Navigation, training

Mode/Industry

Maritime

Type of Paper

Review/empirical

Methodology

Simulator study

Issue Addressed

Training with simulators

Principal Finding

The authors noted that the initial introduction of radar did not include training and resulted in an increase in collisions.

One key issue that training might address is resource management on the bridge. Therefore, training should be considered in detail. In addition, the "video game" phenomena where ships pass more closely to dangerous areas while using radar compared to without, deserves special attention. The paper also provides an interesting approach to increasing the effectiveness of radar. When navigating by radar, or poor visibility, blackening out the windows lead to increased safety.

Deficiencies

Several anecdotal instances of how misused radars might hamper effectiveness, but no theoretical reason why simulator training might help. Therefore, it gives little practical guidance for using simulator training.

Citation

Froese, J. & Heinecke, A. M. (1984). An attempt to integrate information on a multi-colour display. 2nd International Bridge Design & Operation Forum.

Area(s) of Focus

Navigation

Mode/Industry

Maritime

Type of Paper

Theoretical, commentary

Methodology

Prototype development

Issue Addressed

Integration of ship data on bridge displays

Principal Finding

The paper outlines the theoretical basis for the development of prototype displays. For example, the paper illustrates how information at different levels of abstraction might be combined to convey the status of balancing tasks.

Deficiencies

Much of the information seems speculative, and has little empirical basis.

Citation

Gardenier, J.S. (1981). Ship navigational failure detection and diagnosis. U.S. Coast Guard (G-DMT-1/54). Washington, D.C.

Area(s) of Focus

Navigation, automation

Mode/Industry

Maritime

Type of Paper

Commentary

Methodology

Issue Addressed

Human error and the ways of mitigating human error in navigation.

Principal Finding

This paper provides a broad overview of the human role in marine safety. It shows that many marine accidents are a consequence of human error, and that technology like ARPA will not solve problems. This paper shows how human factors theory might be applied to design and operation of ships to reduce the potential for human error.

Deficiencies

Because of the wide variety of issues addressed, this paper lacks detail.

Citation

Goradia, D. (1989). Navigation with an integrated bridge. Shipbuilding Technology, Int., pp. 278-279.

Area(s) of Focus

Navigation, automation

Mode/Industry

Maritime

Type of Paper

Product description

Methodology

Issue Addressed

Integration of navigation and control of ship to maximize safety and efficiency.

Principal Finding

This short paper describes Sperry's computer support for navigation, which integrates GPS, SatNav, and voyage management system information.

Deficiencies

The paper promises increased efficiency and safety, but it gives no mention of how system will integrate with crew.

Citation

Grabowski, M. (1989). Decision aiding technology and integrated bridge design. Presented at the Society of Naval Architects and Marine Engineers Spring Meeting/STAR Symposium, New Orleans, Louisiana.

Area(s) of Focus

Navigation, automation

Mode/Industry

Maritime

Type of Paper

Commentary, empirical

Methodology

Field study

Issue Addressed

Feasibility and utility of expert system decision aids

Principal Finding

The paper stresses the fact that successful systems must consider design of entire bridge, not just isolated components. To achieve this goal, it describes a design process which includes: user requirements, task analysis, man-machine trade-off, software specification. In addition to the discussion of design philosophy, the study examined a crew using an expert system. Using the expert system, to aid decision making, the crew performed more effectively than a crew without the system.

Deficiencies

Statements like "some form of chart representation is often recommended in order to mirror the user's mental representation of the domain" are not supported or fully defined. In addition, the study shows no data, and fails to specify what is meant by superior decision making performance.

Citation

Habberley, J. S. & Taylor, D. H. (1989). Simulated collision avoidance maneuvers: a parametric study. Journal of Navigation, 42(2), 248-254.

Area(s) of Focus

Navigation

Mode/Industry

Maritime

Type of Paper

Empirical

Methodology

Controlled experimentation evaluating combinations of approach angles and speeds.

Issue Addressed

Examined whether watchkeepers used time-to-collision information or distance information as a basis for initiating evasive action

Principal Finding

Mathematical models of radar track data of ship collisions suggests that models of operator behavior might be used to predict potential collision situations. This paper presents the results of a controlled experiment to investigate collision avoidance behavior. The results of this study show that individuals show different, but consistent styles during crash avoidance situations. In addition, some subjects are sensitive to approach speeds of on-coming vessels and others are not. This study suggests that models of operator behavior could help identify potential collision situations, and training could lead to more consistent collision avoidance tactics.

Deficiencies

Application to solve navigation problems may be limited.

Failed to relate subjects' styles with a metric of performance such as point of closest approach or optimality of evasive action (was the course deviation excessive).

Citation

Hadley, M.A. (1988). Present trends in naval bridge design and integrated navigation. Journal of Navigation, 41(2), pp. 276-287.

Area(s) of Focus

Navigation, automation

Mode/Industry

Maritime/military

Type of Paper

Commentary

Methodology

Issue Addressed

Physical layout and information integration of current and future bridge designs

Principal Finding

This paper provides an analysis of the physical layout of the bridge as well as the information that might be displayed to the bridge personnel. The description of the layout ranges from an examination of difficult types of bridge architecture to how best to arrange displays and controls. This paper also speculates on the potential of new technology, such as electronic chart displays.

Deficiencies

Many aspects of military ship designs may have little relevance to commercial shipping. For example, the bridge design specifies the accommodation of 16 people during peak workload.

Citation

Harumasa, H. & Kawashima, S. (1989). The super-rationalized bridge. Shipbuilding Technology Int., pp. 280-282.

Area(s) of Focus

Navigation, automation

Mode/Industry

Maritime

Type of Paper

Product description

Methodology

Issue Addressed

Integration of navigation and control of ship to maximize safety and efficiency.

Principal Finding

Japan Radio Company's (JRC) approach to an integrated bridge control system proposes to integrate much of the navigation instrumentation into a single system. Included in this system is an extensive use of electronic charts.

Deficiencies

This system promises to increase safety and efficiency but gives little mention to how it will integrate with the ship personnel.

Citation

Hayes, J., and Wald, E.D. (1980). Effectiveness of three electronic systems as collision-avoidance and grounding avoidance aids: A simulator investigation in a congested harbor. (CAORF Report No. 13-7811-01). National Maritime Research Center, Kings Point, NY. (NTIS No. PB82-172073). Springfield, VA.

Area(s) of Focus

Navigation

Mode/Industry

Maritime

Type of Paper

Empirical

Methodology

Simulator-based comparison of three displays

Issue Addressed

Effect of different navigation technology on ship safety. This study compared collision avoidance effectiveness of conventional radar, collision avoidance system (CAS), and a collision avoidance system augmented with channel navigation information (CAS+NAV).

Principal Finding

The results of the experiments were subjected to a very thorough analysis. This analysis showed CAS and CAS+NAV to be more effective than conventional radar. The extra information on the CAS+NAV display helped the CAS be more effective than the CAS+NAV when incidents involved close shoals. In addition, CAS and CAS+NAV lead to "bolder" evasive actions and fewer collisions and "close calls."

Deficiencie

Since the experiment artificially limited subjects' information sources it may not be a fair test of the navigation equipment.

Citation

Ibbetson, E.R. (1988). Civil marine radar colour display. Journal of Navigation, 41(2), pp. 256-260.

Area(s) of Focus

Navigation, automation

Mode/Industry

Maritime

Type of Paper

Commentary

Methodology

Issue Addressed

Value of color raster scan radar screens

Principal Finding

The authors state that the raster scan displays are superior, to the traditional radar based on resolution, brightness and flexibility. Likewise, since the brightness is greater more than one person can observe the radar at the same time. In addition to these differences in technology, the authors claim that color can aid observers' interpretation of data.

Deficiencies

Color scheme reported to be accepted by users, but there is no formal evidence for performance enhancement.

Aside from reports of good user acceptance, the paper provides no quantitative comparison of raster scan color displays to a traditional radar.

Citation

International Maritime Organization. (1991, December). Improved design and construction standards for bulk carriers: Computer-aided navigation system for safety (CAN). Submitted by Japan to the Sub-Committee on Ship Design and Equipment, 35th session, agenda item 24. (DE 35/INF.4).

Area(s) of Focus

Navigation, automation

Mode/Industry

Maritime

Type of Paper

Product description

Methodology

Issue Addressed

Provide real-time data on ship/sea conditions and prediction of ship behavior to assist operation in heavy seas.

Principal Finding

Suggests that wave data displays and safety risk indicators will facilitate ship handling.

Deficiencies

No evidence provided to support assertions. Some displays, such as time history and wave spectrum would seem difficult for deck officer to understand and relate to ship handling requirements.

Citation

Larsen, Capt. Per. (1987, October). Overall system reliability standards for one-man bridge operation. Presented at the Third International Conference on Bridge Design and Ship Operation. Paper Series No.: 87 PO12. Oslo, Norway.

Area(s) of Focus

Navigation, automation, manning

Mode/Industry

Maritime

Type of Paper

Commentary

Methodology

Functional analysis

Issue Addressed

Safety and reliability of one-man bridges. Determining information and manpower requirements for navigation.

Principal Finding

The study defines the development of functional requirements as a critical step in system development. The authors claim that whatever the level of automation, it is of prime importance that a functional analysis of the information required to control the ship guide be displayed. The displayed information should not depend on technological capabilities.

Deficiencies

The authors left "Workload" undefined, even though it seemed to be a central factor in the argument.

Likewise, the paper suggests a different workstation for navigation, traffic surveillance, route planning, manual steering and docking, but gives little information about how they might be integrated.

Citation

Maybourn, R. (1987). The navigator - man or machine? Journal of Navigation, 40(3), pp. 334-343.

Area(s) of Focus

Navigation, automation, training

Mode/Industry

Maritime

Type of Paper

Commentary

Methodology

Issue Addressed

Historical background of navigation and potential impact of new technology

Principal Finding

This paper presents a historical perspective of changes in navigation technology, starting from the prehistorical period to the present. The authors argue that new technologies affecting navigation will change the human's role on ships. These changes must be carefully considered, and the technology should be designed with respect to the limits and capabilities of the human operator. Otherwise, the capabilities will not be realized.

Deficiencies

This study presents a historical perspective that illustrates many potential problems, but offers little concrete guidance for design of new systems.

Citation

Moskvin, G.I., & Sorochinsky, V.A. (1988). Integrated navigation and electronic chart display systems. Journal of Navigation, 41(2), pp. 295-299.

Area(s) of Focus

Navigation

Mode/Industry

Maritime

Type of Paper

Commentary

Methodology

Issue Addressed

Integration of navigation data on the bridge

Principal Finding

The paper provides the perspective of bridge design in USSR. This perspective centers on the technical aspects, such as the type of sensor information that should be integrated on the bridge. The authors claim that integrating sensor information with chart data will lead to more efficient ships.

Deficiencies

Description of technological capabilities with no connection to how the changes of bridge technology would affect the demands imposed on operators.

Citation

Plumridge, M.J.M. (1987, October). What electronic chart display do mariners want in 1990? Seaways, pp. 5-6.

Area(s) of Focus

Navigation

Mode/Industry

Maritime

Type of Paper

Commentary

Methodology

Issue Addressed

Proposed specifications for ECDIS (Electronic Chart and Display Information Systems)

Principal Finding

This paper presents an example method of formatting an ECDIS as a means of soliciting comments. It integrates all navigation aids into a simple displays, requiring two high quality 19" displays. One display shows the minimum information needed for navigation, and the other shows supplemental information.

Deficiencies

Failed to specify aspects of displays such as: how maps would scroll; color scheme; how the two displays might be used; and how scales are chosen and changed.

Citation

Reynolds, J. (1984). Research into the use of VDU's on the bridge of tomorrow. Proceedings of the Second International Bridge Design and Operation Forum.

Area(s) of Focus

Navigation

Mode/Industry

Maritime

Type of Paper

Empirical

Methodology

Field study

Issue Addressed

Examined three aspects of electronic support in the wheelhouse: a command display that showed safety critical information, an electronic chart, and a log of economic/efficiency information.

Principal Finding

Through observations and surveys this paper examined prototype displays. One of the primary results was that the need to use trial equipment in parallel with traditional equipment distorted operators' usage pattern, resulting in higher workload. The result emphasizes the importance of careful training and implementation of technology before it is tested.

Operators accepted the command displays but found the electronic chart unacceptable because of data deficiencies and limits in display technology.

Deficiencies

This paper presents little justification for design decisions used in the experiment. In addition, it only presents qualitative information based on operator's opinions. The paper presents no information about performance.

Citation

Rogoff, M. (1990-91, Winter). Electronic charts in the nineties. Journal of The Institute of Navigation, 37(4), pp. 305-318.

Area(s) of Focus

Navigation, automation

Mode/Industry

Maritime

Type of Paper

Commentary

Methodology

Issue Addressed

Technical and administrative aspects of ECDIS

Principal Finding

The paper discusses the technical possibilities of integrating chart information with radar, traditional chart, and GPS data. In addition, the report also discusses the administrative aspects involved with the development of IMO standards and sea trials of prototypes. The report concludes with a view of the future role of ECDIS, in the context of an integrated bridge. The authors argue that the insistence that the ECDIS match paper charts exactly may inhibit the potential value of ECDIS. They argue that other safety-critical information, such as radar, needs to be incorporated into the chart.

Deficiencies

The paper lacks any clear position for a formal assessment of ECDIS and traditional systems. The author seems to hold the assumption that after all the technical and administrative barriers have been crossed, then the system will help the operator. However, human-machine interface problems may be significant, and without sufficient attention, they may reduce the effectiveness to below that of paper charts.

Citation

Rossano, M.J., & Warren, D.H. (1989). Misaligned maps lead to predictable errors. Perception, 18, (pp. 215-229).

Area(s) of Focus

Navigation

Mode/Industry

Basic research

Type of Paper

Empirical

Methodology

Laboratory research using simplified 4-point maps with locomotor and pointer response to queries about directions on map

Issue Addressed

Errors in making judgments about maps

Principal Finding

The paper claims that errors made due to map orientation is a general effect not specific to experimental methodology. Therefore, these results may predict errors in responses related to differences in map orientation through a hypothesized mental process. This study found subjects made errors related to misalignment of the map or they made errors corresponding to the mirror image of the correct location. These two types of errors correspond to strategies subjects might use: mental rotation or mentally flipping the map. The authors argue that the persistence of these effects over a variety of experimental conditions makes it likely that they will be reflected in actual map use.

Deficiencies

"Maps" used may be so simplified as to limit the generality of the results. Subjects task and experience may make transfer of results to ship-based navigation problematic.

Citation

Schudlich, D. (1990). Integrated ship management and control. Shipbuilding Technology, pp. 177-178.

Area(s) of Focus

Navigation, automation

Mode/Industry

Maritime

Type of Paper

Commentary

Methodology

Issue Addressed

Integration of ship management and control

Principal Finding

Effective integration requires careful consideration of what information should be presented and how it should be presented.

Deficiencies

Primarily a description of the new information system for the Hupag Lloyd "ships of the future", listing functions and features of the system.

The article contains many vague statements about the need to integrate humans and the ship information system.

Citation

Schuffel, H., Boer, J.P.A., & van Breda, L. (1988). The ship's wheelhouse of the nineties: the Navigation performance and mental workload of the officer of the watch. Journal of Navigation, 42(1), pp. 60-72.

Area(s) of Focus

Navigation

Mode/Industry

Maritime

Type of Paper

Empirical, theoretical

Methodology

Simulation study

Issue Addressed

Feasibility of one-man bridge

Principal Finding

This paper provides both an analytic and empirical approach to bridge evaluation. Since control behavior is based on feedback control rather than preplanned control, the accuracy and frequency of the automatic plotting will facilitate performance. A continuous memory task, used as a secondary task measure of workload shows that integrating information enables an advanced design one-man bridge to perform as well as a two-man bridge. In addition, the 1-man bridge performed better with respect to navigation accuracy. The study also incorporates a task element and a task function matrix to categorize 100 maritime accidents and determine whether the new bridge design would have prevented the accidents.

Deficiencies

The study fails to provide support for their claim that the new design would have prevented accidents. In addition, the simulator study only examined normal operation and not emergency situations where operator might be forced to use more manual control, resulting in a potential overload situation.

Citation

Stoop, J. (1990). Redesign of bridge layout and equipment for shipping vessels. Journal of Navigation, 43(2), pp. 215-228.

Area(s) of Focus

Navigation, automation

Mode/Industry

Maritime

Type of Paper

Accident analysis, model development

Methodology

Accident analysis and analytic timeline model

Issue Addressed

Use of cognitive model of human error, together with a normative task description, to provide a basis for design changes

Principal Finding

This paper shows how human factors analysis could be used to identify needed design changes. As part of this analysis, skill-, rule-, and knowledge-based performance tasks were arranged on a timeline to estimate workload. The authors stress the need to evaluate residual risks, and problems generated by introducing solutions. Overall this paper shows how models of cognitive psychology can explain and predict errors.

Deficiencies

Analysis developed for fishing vessels, so it would require revision before it could be applied to cargo ships.

Citation

van Opstal, L.H. (1988). Standardization of electronic charts. Journal of Navigation, 41(2), pp. 288-294.

Area(s) of Focus

Navigation

Mode/Industry

Maritime

Type of Paper

Commentary

Methodology

Issue Addressed

Implementation of electronic charts

Principal Finding

This paper discuses some of the features and functions electronic charts should have. However, research and field experience are required to guide the development of standardized electronic charts. This paper identifies some areas of particular concern: 1) charts with zoom feature need to be constructed so that the zoom feature doesn't mislead viewers with perception of chart accuracy, 2) development of "minimum data set" for safe navigation, 3) research is needed to specify symbol, shape, and color.

Deficiencies

Although the paper gives many exact guidelines, it also leaves many issues unanswered. Many issues are said to require additional research.

Citation

Veldhuyzen, W., & Stassen, H.G. (1977). The internal model concept: An application to modeling human control of l ge ships. Human Factors, 19(4), pp. 367-380.

Area(s) of Focus

Navigation, Manning

Mode/Industry

Maritime

Type of Paper

Model development

Methodology

Control theoretic model of ship controls

Issue Addressed

The feasibility of using a simulation model to study the influence of additional information on the performance of helmsmen steering ships with different levels of stability.

Principal Finding

This paper describes the development of a non-linear continuous model of the helmsman's behavior. This model consisted of an estimate of the helmsman's internal model and decision making elements. It included the ability to predict behavior in both calm and heavy seas.

Deficiencies

The model has limited applicability in manning decisions, but it may be a useful tool in determining the effectiveness of newly developed display technology.

ORGANIZATIONAL

Organizational variables have been attributed to a variety of unsafe practices in the maritime industry. In particular, the Exxon Valdez can be viewed as the result of combined organizational and human performance failures (the latter possibly resulting from the former). Relatively little study has been devoted to the organizational factors related to safety in the maritime industry; this section reviews selected articles concerned with this issue.

Reference List

Bryant, D. (Ed.). (1991). The human element in shipping casualties. London: Marine Directorate of the Department of Transportation.

McKenna, J.T. (1992, January). Airlines study human factors' role in boosting efficiency of mechanics. Aviation Week & Space Technology, pp. 54-55.

Paté-Cornell, M.E. (1992, January). Management of human error in operations of murine systems. A port-mortem analysis of the Piper Alph Accident: Technical and Organizational Factors. (Report No. HOE-92-2). Berkeley, CA: University of California, Department of Naval Architecture & Offshore Engineering.

Perrow, C. (1984). Normal accidents - Living with high-risk technologies. New York: Basic Books.

Roberts, K.H., & Moore, W.H. (1992, January). Management of human error in operations of marine systems. A Gordon Knot: Into which sailed the Exxon Valdez. (Report No. HOE-92-1). Berkeley, CA: University of California, Department of Naval Architecture & Offshore Engineering.

U.S. Department of Transportation, United States Coast Guard. (1990, August) Recommendation concerning management practices for safe ship operation and pollution prevention. Navigation and Vessel Inspection Circular, No. 1-90.

Citation

Bryant, D. (Ed.). (1991). The human element in shipping casualties. London, England: Marine Directorate of the Department of Transport.

Area(s) of Focus

Organizational

Mode/Industry

Maritime

Type of Paper

Accident analysis

Methodology

Task/Function/Analysis, Historical record analysis

Issue Addressed

The human factors involved in collisions, fires and grounding.

Principal Finding

This study suggests reducing the delay between casualty occurrence and reports, potentially resulting in an on-board reporting system. Casualty reports should be reviewed by a number of disciplines, including human factors. One prospective enhancement would be an anonymous reporting system, which would likely increase the number of reports. In order to obtain better data concerning human factors, it is recommended that improvements be made in the structure, timing, and order of investigation questions, possibly through use of a checklist.

Deficiencies

Citation

McKenna, J. T. (1992, January). "Airlines study human factors' role in boosting efficiency of mechanics." Aviation Week & Space Technology, pp. 54-55.

Area(s) of Focus

Organizational

Mode/Industry

Aviation

Type of Paper

Survey

Methodology

Issue Addressed

Increased cost and safety by improving Human Factors in maintenance.

Principal Finding

Communications is key element in maintenance. Boeing 777 design will include On-Board maintenance system for the mechanic. With this job the goal is to solve problems in 50 minutes. Other improvements involve simple solutions, e.g., better hangar lighting. US Air provides 24-hour contact number to help mechanics with engineering orders. Designers are using HUMAN CAD to determine maintainability.

Deficiencies

Citation

Paté-Cornell, M. E. (1992, January). Management of human error in operations of marine systems. A post-mortem analysis of the Piper Alpha Accident: Technical and Organizational Factors. (Report No. HOE-92-2). University of California, Berkeley: Dept. of Naval Architecture & Offshore Engineering.

Area(s) of Focus

Organizational

Mode/Industry

Maritime (Offshore oil platform)

Type of Paper

Accident analysis

Methodology

Analysis of events

Issue Addressed

Causes of fire and organizational problems.

Principal Finding

Principal cause attributed to valve leak and failure of crew to communicate about removal of 1 condensate injection pump, and failure to tighten flange on inoperative pump. Operators on duty failed to notice increased flare because of inexperience, and failed to check source of alarms. Organizational pressures for increased levels of production stressed the equipment and personnel.

Deficiencies

Root cause is indeterminate in this type of analysis.

Citation

Perrow, C. (1984). Normal accidents - Living with high-risk technologies. New York: Basic Books.

Area(s) of Focus

Organizational, training, automation

Mode/Industry

Maritime and others

Type of Paper

Review, accident analysis

Methodology

Issue Addressed

The causes of severe accidents

Principal Finding

Marine accidents continue to occur despite advances in safety technology. The author cites four possible causes: the captain, structure of the industry and insurance practices, organization of personnel on board, and difficulty of national and international regulation. The author found that regulations often differ among countries and are not well enforced if they exist. This often leads to the lack of operational safety equipment and overwork of the crew. The crews are often poorly organized for tasks, and unnecessarily overworked at times. In addition, companies pressure captains to shorten travel and port times. This adds to fatigue in port and the use of safety equipment to take greater risks rather than increasing the safety margin the equipment could afford. Incompetence and complacency of the captain are also contributing factors to accidents. The insurance for ships is not rewarding of safety, but forces industry heads to maximize the days at sea.

Deficiencies

Some of the examples are very dated, nineteenth century or earlier. For example, it is unclear if selection procedures have lessened captain incompetence as a factor in maritime accidents.

Citation

Roberts, K. H. & Moore, W. H. (1992, January). Management of human error in operations of marine systems. A Gordian Knot: Into which sailed the Exxon Valdez. (Report No. HOE-92-1). University of California, Berkeley: Dept. of Naval Architecture & Offshore Engineering.

Area(s) of Focus

Organizational

Mode/Industry

Maritime

Type of Paper

Review

Methodology

Analysis of event sequences; interdependencies

Issue Addressed

Organizational and personnel deficiencies leading to accident.

Principal Finding

Evolution of poor practices occurred over time in all organizations involved -- Exxon (reduced staffing, poor monitoring of personnel), USCG (failure to follow VTS procedures, deterioration of equipment) and Alyeska (reduced drill frequency, failure to inventory equipment). Recommends total play out of drill to identify information regarding response preparedness (equipment needs, based on PGE approach at Diablo Canyon). The report also recommends that organizations include a full-time contingency response team.

Deficiencies

Restates principal findings of National Transportation Safety Board.

Citation

U.S. DOT, United States Coast Guard. (1990, August). Recommendation concerning management practices for safe ship operation and pollution prevention. Navigation and Vessel Inspection Circular, No. 1-90.

Area(s) of Focus

Organizational

Mode/Industry

Maritime

Type of Paper

Regulation/Standard

Methodology

Issue Addressed

Call attention to IMO Guidelines on management for the safe operation of ships for oil pollution prevention.

Principal Finding

This paper discusses a framework for the development of pollution prevention practices. This discussion includes general statements concerning the role of management, crew, and masters in pollution prevention.

Deficiencies

Guidelines are too general to provide specific recommendations.

TRAINING

Training problems have been implicated in maritime accidents, both in terms of technical training, and "process" training concerned with communication between crew members. Relatively few articles collected for this bibliography addressed training directly, and they are presented in this section.

Reference List

American Petroleum Institute. (1991). Guidelines for developing bridge management teams: API recommended practice 1i40. Washington, D.C.

Congressional Record. 96th Congress, First Session. (1978). International convention on standards of training, certification and watchkeeping for seafarers, with annex. (Message from the President of the United States).

Esbensen, P., Johnson, R.E., & Kayten, P. (1985). The importance of crew training and standard operating procedures in commercial vessel accident prevention. Proceedings of STAR symposium, Norfolk, VA, May 21-24, 1985 (pp. 285-307). Jersey City, NJ: The Society of Naval Architects and Marine Engineers.

Rouse, W.B. (1990). Training and aiding personnel in complex systems. In H.R. Boder (Ed.) Manprint: An approach to systems integration. (pp. 417-432). New York: VanNostrand Reinhold.

Wagenaar, W.A., & Groeneweg, J. (1987). Accidents at sea: Multiple causes and impossible consequences. International Journal of Man-Machine Studies, 27, 587-598.

Citation

American Petroleum Institute. (1991). Guidelines for developing bridge management teams: API recommended practice 1140. Washington, D.C.

Area(s) of Focus

Training, organizational

Mode/Industry

Maritime

Type of Paper

Commentary

Methodology

Guideline development

Issue Addressed

Guidance for bridge management team education and training

Principal Finding

Recommends that bridge management courses include material on team organization, ship handling, navigation proficiency, communications proficiency, voyage planning, bridge team - pilot relations, and documentation.

Deficiencies

Confusion - many of the skills to be trained (e.g., navigation proficiency) are technical, but deficiencies are to be dealt with elsewhere. Course recommendations focus on technical skills and do not focus on stated objectives.

Citation

Cong. Rec. 96th Congress, 1st Session. (1978). International convention on standards of training, certification and watchkeeping for seafarers, with annex, 1978. (Message from the President of the United States).

Area(s) of Focus

Training

Mode/Industry

Maritime

Type of Paper

Regulation/Standard

Methodology

Issue Addressed

Training, certification, and watchkeeping.

Principal Finding

Specifies performance demonstrations of competence on electronic gear for deck officers; specifies content of special training courses for oil, chemical, and LNG tankers; outlines specific duties of some licensed personnel (possible basis for JTA). This can be used as possible basis for U.S. exam validation.

Deficiencies

Citation

Esbensen, Paul, Johnson, Ralph E., Kayten, Phyllis. (1985). The importance of crew training and standard operating procedures in commercial vessel accident prevention. In Proceedings of STAR Symposium, Norfolk VA, May 21-24, 1985 (pp. 285-307).Pub?Society of Naval Architects and Marine Engineers.

Area(s) of Focus

Training, navigation

Mode/Industry

Maritime

Type of Paper

Accident analysis

Methodology

Issue Addressed

The role of human error in maritime accidents, especially those errors related to insufficient training or procedures.

Principal Finding

This paper provides an analysis of ten specific accidents, showing how training and procedures might have mitigated these accidents. In addition, the paper examines some of the limitations of the current accident reporting system. The paper concludes that training of personnel and establishing standard operating procedures are vital issues necessary to meet the demands imposed by increasing technological sophistication of today's ships.

Deficiencies

Citation

Rouse, W.B. (1990). Training and aiding personnel in complex systems. In H.R. Boder (Ed.), Manprint: An approach to systems integration. pp. 417-432. New York: VanNostrand Reinhold.

Area(s) of Focus

Training

Mode/Industry

Military

Type of Paper

Review, theoretical

Methodology

Issue Addressed

This paper develops an analytic approach to guide use of resources on either aiding or training.

Principal Finding

This paper presents a taxonomy of knowledge needed to interact with the system, combined with training methods to ensure operators have that knowledge. In addition, it presents a taxonomy of aiding approaches that could be selected based on decision making tasks facing the operators.

Deficiencies

While this paper provides a useful approach to training and aiding, it would require significant efforts to tailor it to the maritime industry.

Citation

Wagenaar, W.A., & Groeneweg, J. (1987). Accidents at sea: Multiple causes and impossible consequences. International Journal of Man-Machine Studies, 27, pp. 587-598.

Area(s) of Focus

Training, organizational

Mode/Industry

Maritime

Type of Paper

Accident analysis

Methodology

Analysis of 100 accident reports using causal networks

Issue Addressed

The nature of accidents at sea and the implications for generating solutions

Principal Finding

This report concludes that accidents appear as a result of highly complex coincidences which could rarely be foreseen by those involved. In addition, they claim accidents occur because behavior is not seen as being risky. Therefore, to prevent accidents, operators need to be better trained, not simply told to act more safely.

Deficiencies

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Beetham, E.H. (1989, February). Bridge manning. Seaways, pp. 3-7. **Manning**

Bittner, A.C., Jr., & Guignard, J.C. (1988). Shipboard evaluation of motion sickness incidence. Trends in Ergonomics/Human Factors V, pp. 529-539. **Fatigue/Incapacitation**

Booher, H.R., & Hewitt, G.M. (1990). Manprint tools and techniques. In H.R. Booher (Ed.), MANPRINT: An approach to systems integration pp. 343-390. New York: Van Nostrand Reinhold. **Manning**

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Bryant, D. (Ed.). (1991). The human element in shipping casualties. London: Marine Directorate of the Department of Transportation. **Organizational**

46 Code of Federal Regulations, Part 50 et al. (1988, May 18). Part II: Department of Transportation/Coast Guard, Vital system Automation; Final Rule. Washington, DC: U.S. Government Printing Office. **Automation, manning**

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Colquhoun, W.P., Rutenfranz, J., Goethe, H., Neidhart, B., Condon, R., Plett, R., & Knauth, P. (1988). Work at sea: a study of sleep, and of circadian rhythms in physiological and psychological functions, in watchkeepers on merchant vessels: I. Watchkeeping on board ships: a methodological approach. Occupational and Environmental Health, 60, 321-329. **Fatigue/Incapacitation**

Colquhoun, W.P., Watson, K.J., Gordon, D.S. (1987). A shipboard study of a four-crew rotating watchkeeping system. Ergonomics, 30(9), 1341-1352. **Fatigue/Incapacitation**

Condon, R., Colquhoun, W.P., Knauth, P., Plett, R., Neidhart, B., DeVol, D., Eickhoff, S., Rutenfranz, J. (1988). Work at sea: A study of sleep, and of circadian rhythms in physiological and psychological functions, in watchkeepers on merchant vessels: V. Effects of time zone crossings. Occupational and Environmental Health, 61, 39-49. **Fatigue/Incapacitation**

Condon, R., Colquhoun, W.P., Plett, R., DeVol, D., & Fletcher, N. (1988). Work at sea: A study of sleep, and of circadian rhythms in physiological and psychological functions, in watchkeepers on merchant vessels: IV. Rhythms in performance and alertness. Occupational and Environmental Health, 60, 405-411. **Fatigue/Incapacitation**

Congressional Record. 96th Congress, First Session. (1978). International convention on standards of training, certification and watchkeeping for seafarers, with annex. (Message from the President of the United States). **Training**

Connaughton, S.T. (February/March 1988). Federal rules on operating a commercial vessel while intoxicated. Proceedings of the Marine Safety Council, 45(2), 40-43. **Fatigue/Incapacitation**

Connaughton, S.T. (1987). Coast Guard Merchant Vessel Manning, No. 10. Proceedings of 1987 Ship Operations, management and Economics International Symposium, Kings Point, New York, September 17-18, 1987 (pp. 10-1-10-7). **Manning**

Craig, A., & Condon, R. (1984). Operation efficiency and time of day. Human Factors Society, 26(2), 197-205. **Fatigue/Incapacitation**

De Keyser, V.D. (1987). How can computer-based visual displays aid operators? International Journal Man-Machine Studies, 27, 471-478. **Automation**

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ERGOSEA 81: The Second International Conference on Human Factors at Sea. Conference held October 5-8, 1981. **Fatigue/Incapacitation**

Esbensen, P., Johnson, R.E., & Kayten, P. (1985). The importance of crew training and standard operating procedures in commercial vessel accident prevention. Proceedings of STAR symposium, Norfolk, VA, May 21-24, 1985 (pp. 285-307). Jersey City, NJ: The Society of Naval Architects and Marine Engineers. **Training, navigation**

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Froese, J. & Heinecke, A.M. (1984). An attempt to integrate information on a multi-colour display. Second International Bridge Design & Operation Forum. **Navigation**

Gaffney, M.E. (1987). Reduced manning in the liner trades: Technological capabilities and organizational implications. Washington, DC: National Academy of Sciences, Maritime Transportation Research Board. **Manning**

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Grabowski, M. (1989). Decision aiding technology and integrated bridge design. Presented at the Society of Naval Architects and Marine Engineers Spring Meeting/STAR Symposium, New Orleans, LA. **Navigation, automation**

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Habberley, J.S. & Taylor, D.H. (1989). Simulated collision avoidance maneuvers: a parametric study. Journal of Navigation, 42(2), 248-254. **Navigation**

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Hansen, A. (1989). One-man control from the bridge. Shipbuilding Technology Int., pp. 275-277. **Automation, manning**

Harbour, J.L. & Hill, S.G. (1990). Using HSYS in the analysis of human-system interactions: Examples from the offshore petroleum industry. Proceedings of the Human Factors Society 34th Annual Meeting, (pp. 1190-1194). **Automation**

Harding, E.J. (1975, March). Computer-based ship automation developments in the United Kingdom and abroad. Proceedings of the Symposium on the Use of Computers in Shipboard Automation (pp. 11-26). London: The Royal Institution of Naval Architects. **Automation**

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